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ABSTRACT

The Colorado Model Content Standards for Science specify what all students should know and be able to do in science as a result of their school studies. These standards reflect high expectations and outline the essential level of science knowledge and skills needed by all citizens to participate productively in an increasingly technological society. Six standards are presented with their rationale and specific expectations for students completing grades K-4, 5-8, and 9-12. (ASK)

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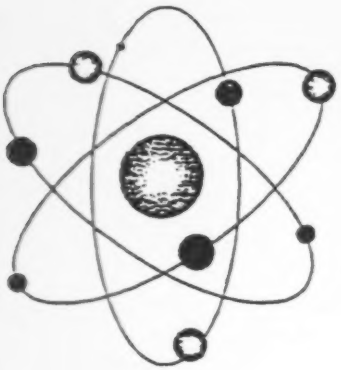

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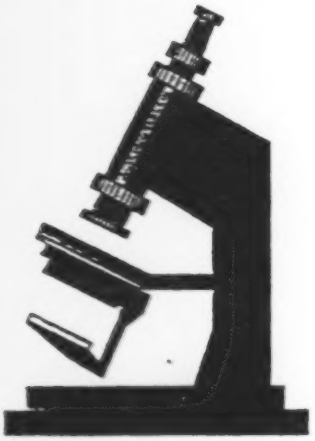

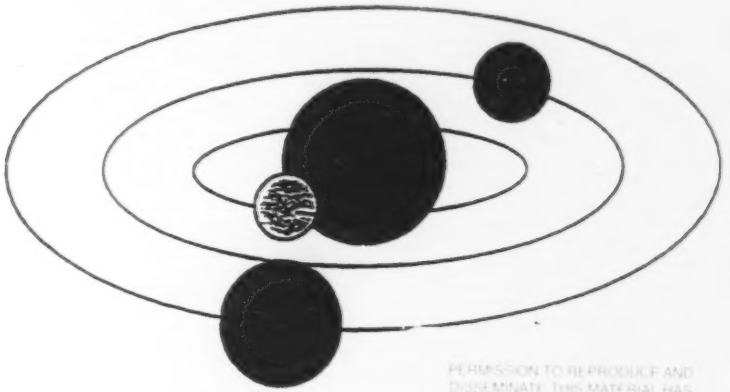

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INTRODUCTION

Colorado Model Content Standards for Science

The Colorado model standards presented here specify what all students should know and be able to do in science as a result of their school studies. Specific expectations are given for students completing grades K-4, 5-8, and 9-12. These standards reflect high expectations and outline the essential level of science knowledge and skills needed by all citizens to participate productively in our increasingly technological society. Some suggestions are also offered for those students who elect to extend their study of science beyond that specified in these content standards, based on their particular interests, motivation, career goals, and needs.

In 1992, the National Committee for Science Education Standards and Assessment (NCSESA), which directed the National Research Council's development of K-12 national science education standards, issued guiding principles for its work. This statement provides useful perspective on the purpose and eventual use of Colorado model science content standards:

> "In particular, the commitment to 'Science for All' implies inclusion not only of those who traditionally have received encouragement and opportunity to pursue science, of women and girls, all racial and ethnic groups, the physically and educationally challenged, and those with limited English proficiency. Further, it implies attention to various styles of learning and differing sources of motivation. Every person must be brought into and given access to the ongoing conversation of science."
>
> *NCSESA, 1992*

In that spirit, these model science standards define the level of science knowledge and proficiency that all Colorado students should gain in their school studies. The goal is to have students apply scientific information and processes to practical problems in an ethical and safe manner.

The view of the nature of science conveyed in these content standards can be summarized through this excepted material from Science for All Americans, published by the American Association for the Advancement of Science in 1990:

> Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systemic study. Scientists believe that through the use of the intellect, and with the aid of instruments that extend the senses, people can discover patterns in all of nature. Science is a process for producing knowledge. Change in scientific knowledge is inevitable because new observations may challenge prevailing theories. In science, the testing and improving and occasional discarding of theories, whether new or old, go on all the time. However, the modification of ideas, rather than their outright rejection, is the norm in science, as powerful constructs tend to survive and grow more precise and to become widely accepted. Continuity and stability are as characteristic of science as change is, and confidence is as prevalent as tentativeness.

The numerical order of the six science content standards does not imply any particular judgments regarding their relative importance or teaching priorities. In fact, as the document emphasizes, Standards 1, 5, and 6—relating to scientific investigations, applications, and connections—should be addressed through teaching subject matter from the physical, life, and earth/space sciences (Standards 2, 3, and 4). Even though the six science content standards are identified separately, they represent interconnected expectations for students.

The organization of these content standards into six categories does not imply that standards-based science must be taught in separate units or courses that carry these particular titles. The student proficiencies in science can be supported within courses organized in a variety of ways, ranging from integrated and interdisciplinary approaches, to instruction built on major scientific themes, as well as more conventional subject- or discipline-specific approaches. Regardless of how science instruction is organized, these model standards specify the core knowledge and skills that all students should acquire.

Even though these science content standards represent high expectations for all students, they can be reached only if students are provided appropriate science instruction at *all* grade levels. If K-4 science content standards, for example, are designated as the responsibility of only fourth grade (or even third and fourth grade) teachers, this will place an unfair (and instructionally irresponsible) burden on both those teachers and their students. These standards are set with the expectation that science-related activities will occur at *all* grade levels—from initial explorations in kindergarten through increasingly organized and focused science instruction in higher grades.

These content standards were developed by a group of experienced Colorado science educators whose efforts have been guided—at least in part—by related work at the national level focused on defining what all students should know and do in science. The *Benchmarks* from the American Association for the Advancement of Science's *Project 2061* and draft reports from the National Science Education Standards Project at the National Research Council have been particularly useful and influential. References to those documents and to others consulted are listed on page S-28.

Colorado Model Content Standards For Science

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Colorado Model Content Standards

SCIENCE

1. Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.

2. Physical Science: Students know and understand common properties, forms, and changes in matter and energy.

3. Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.

4. Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.

5. Students know and understand interrelationships among science, technology, and human activity and how they can affect the world.

6. Students understand that science involves a particular way of knowing and understand common connections among scientific disciplines.

STANDARD 1:

Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.

RATIONALE

In everyday life, we find ourselves gathering and evaluating information (data), noting and wondering about patterns and regularities, devising and testing possible explanations for how things work, and discussing ideas with others. These characteristically human activities mirror in many ways how scientists think and work. Scientific investigation (inquiry) often begins with a question or problem and usually ends with further questions to investigate. Such investigations may include long-term field studies and are not limited to direct experimentation in a lab setting. They involve the identification and control of variables. Inquiry in the science classroom helps students develop a useful base of scientific knowledge, communicated in increasingly mathematical and conceptual ways as they progress through school. In addition, scientific inquiry stimulates student interest, motivation, and creativity. Designing and conducting investigations encourages students to interpret, analyze, and evaluate what is known, how we know it, and how scientific questions are answered. The knowledge and skills related to scientific inquiry enable students to understand how science works, and are powerful ways for students to build their understanding of the scientific facts, principles, concepts, and applications that are described in the other science content standards, particularly standards two, three, and four. To comprehend the world around them, students need opportunities to pursue questions that are relevant to them and to learn how to conduct scientific investigations. Some scientific inquiries can only be investigated by the use of models since actual events are not repeatable.

GRADES K-4

In grades K-4, what students know and are able to do includes

- asking questions and stating predictions (hypotheses) that can be addressed through scientific investigation;
- selecting and using simple devices to gather data related to an investigation *(for example, length, volume, and mass measuring instruments, thermometers, watches, magnifiers, microscopes, calculators, and computers)*;
- using data based on observations to construct a reasonable explanation; and
- communicating about investigations and explanations.

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GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- identifying and evaluating alternative explanations and procedures;
- using examples to demonstrate that scientific ideas are used to explain previous observations and to predict future events (*for example, plate tectonics and future earthquake activity*);
- asking questions and stating hypotheses that lead to different types of scientific investigations (*for example, experimentation, collecting specimens, constructing models, researching scientific literature*);
- creating a written plan for an investigation;
- using appropriate tools, technologies, and measurement units to gather and organize data;
- interpreting and evaluating data in order to formulate conclusions;
- communicating results of their investigations in appropriate ways (*for example, written reports, graphic displays, oral presentations*);
- using metric units in measuring, calculating, and reporting results;
- explaining that scientific investigations sometimes result in unexpected findings that lead to new questions and more investigations; and
- giving examples of how collaboration can be useful in solving scientific problems and sharing findings.

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- asking questions and stating hypotheses, using prior scientific knowledge to help guide their development;
- creating and defending a written plan of action for a scientific investigation;
- selecting and using appropriate technologies to gather, process, and analyze data and to report information related to an investigation;
- identifying major sources of error or uncertainty within an investigation (*for example, particular measuring devices and experimental procedures*);
- constructing and revising scientific explanations and models, using evidence, logic, and experiments that include identifying and controlling variables;
- communicating and evaluating scientific thinking that leads to particular conclusions;
- recognizing and analyzing alternative explanations and models; and
- explaining the difference between a scientific theory and a scientific hypothesis.

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For students continuing their science education beyond the standards, what they know and are able to do **may** include

- designing and completing an advanced scientific investigation—either individually or as part of a student team—that extends over several days or weeks; and
- continuing to practice and apply inquiry skills as they extend their understanding of science content through further study.

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STANDARD 2:

Physical Science: Students know and understand common properties, forms, and changes in matter and energy. *(Focus: Physics and Chemistry)*

2.1 Students know that matter has characteristic properties, which are related to its composition and structure.

RATIONALE

Everyone has experience with matter in a variety of forms. Such experiences help build students' understanding of similarities and differences in the properties of matter. Their personal experiences help students understand common properties such as hardness, strength, color, shape, and states of matter (solid, liquid, and gaseous). Knowledge of observable properties of matter and its structure and composition is helpful in considering matter's varied uses, availability, and limitations in our world.

GRADES K-4

In grades K-4, what students know and are able to do includes

- examining, describing, classifying, and comparing tangible objects in terms of common physical properties (*for example, state of matter, size, shape, texture, flexibility, color*);
- measuring common physical properties of objects (*for example, length, mass, volume, temperature*); and
- creating mixtures and separating them based on differences in properties (*for example, salt and sand, iron filings and soil, oil and water*).

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- examining, describing, comparing, measuring, and classifying objects based on common physical and chemical properties (*for example, states of matter, mass, volume, electrical charge, temperature, density, boiling points, pH, magnetism, solubility*);
- separating mixtures of substances based on their properties (*for example, solubility, boiling points, magnetic properties, densities*);
- classifying and describing matter in terms of elements, compounds, mixtures, atoms, and molecules (*for example, copper is an element, water is a compound, air is a mixture*); and
- developing simple models to explain observed properties of matter (*for example, using a particle model to account for the solubility of a substance*).

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GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- examining, describing, measuring, classifying, and predicting common properties of substances *(for example, electrical charge, chemical reactivity, acidity, electrical conductivity, radioactivity, relationships in the periodic table);*
- describing and explaining properties and composition of samples of matter using models *(for example, atomic and molecular structure, the periodic table);*
- separating substances based on their chemical and physical properties *(for example, color, solubility, chemical reactivity, melting point, boiling point);* and
- using word and chemical equations to relate observed changes in matter to its composition and structure.

Page S-13 contains content suggestions for students who continue their science study beyond the scope of this standard.

2.2 Students know that energy appears in different forms, and can move (be transferred) and change (be transformed).

RATIONALE

Energy is a central concept in science because all physical interactions involve changes in energy. Students need to understand that all physical events involve transferring energy or changing one form of energy into another. When a transformation of energy takes place, some of it is likely to appear as heat. Knowledge of forms of energy, its transfer and transformation, is essential to interpreting, explaining, predicting, and influencing change in our world.

GRADES K-4

In grades K-4, what students know and are able to do includes

- recognizing that energy *(for example, light, heat, motion, sound, mechanical)* can affect common objects and is involved in common events;
- making observations and gathering data on quantities associated with energy, movement, and change *(for example, distances for a bean-launcher, time for a melting ice cube)*; and
- comparing quantities associated with energy movement and change by constructing simple diagrams or charts *(for example, graph of launch distances, chart of melting time)*.

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GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- measuring quantities associated with energy forms (*for example, temperature, mass, speed, distance, electrical charge, current, voltage)*; and
- describing qualitative and quantitative relationships, using data and observations and graphs, associated with energy transfer or energy transformation (*for example, speed of object vs. height of ramp; length of string vs. pitch of sound; electric current vs. volume of gas produced in electrolysis, with length of time kept constant).*

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- identifying, measuring, calculating, and analyzing quantitative relationships involved with energy forms (*for example, heat transfer in a system involving mass, specific heat, and change in temperature of matter)*; and
- identifying, measuring, calculating, and analyzing qualitative and quantitative relationships associated with energy transfer or energy transformation (*for example, changes in temperature, velocity, potential energy, kinetic energy, conduction, convection, radiation, voltage, current).*

Page S-13 contains content suggestions for students who continue their science study beyond the scope of this standard.

2.3 Students understand that interactions can produce changes in a system, although the total quantities of matter and energy remain unchanged.

RATIONALE

Interactions between matter and energy account for changes observed in everyday events. Understanding how matter and energy interact extends students' knowledge of the physical world and allows them to monitor and explain a wide variety of changes and to predict future physical and chemical changes. Students gain both a practical and conceptual understanding of the laws of conservation of matter and energy.

GRADES K-4

In grades K-4, what students know and are able to do includes

- observing and describing parts of system (*for example, water in a closed jar, water in an open jar, a plant terrarium)*;
- describing an observed change (*for example, a melting ice cube, crystal growth, burning candle, physical breakage)* in terms of starting conditions, type of change, and ending conditions, using words, diagrams, or graphs; and

- predicting what changes and what remains unchanged when matter experiences an external influence (*for example, a push or pull, addition or removal of heat, division of clay into pieces, melting an ice cube, changing a ball of clay to a flattened shape*).

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- identifying and classifying factors causing change within a system (*for example, force, light, heat*);
- identifying and predicting what will change and what will remain unchanged when matter experiences an external force or energy change (*for example, boiling a liquid; comparing the force, distance, and work involved in simple machines*);
- observing and gathering data to support the concept of conservation of mass within a closed system (*for example, precipitation reaction, forming mixtures, gas production*);
- describing, measuring (*for example, temperature, mass, volume, melting point of a substance*) and calculating quantities before and after a chemical or physical change within a system (*for example, temperature change, mass change, specific heat*); and
- describing, measuring (*for example, time, distance, mass, force*) and calculating quantities that characterize moving objects and their interactions within a system (*for example, force, velocity, acceleration, potential energy, kinetic energy*).

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- identifying, describing, and explaining physical and chemical changes involving the conservation of matter and energy (*for example, oscillating pendulum/spring, chemical reactions, nuclear reactions*);
- observing, measuring, and calculating quantities to demonstrate conservation of matter and energy in chemical changes (*for example, acid-base, precipitation, oxidation-reduction reactions*), and physical interactions of matter (*for example, force, work, power*);
- describing and predicting chemical changes (*for example, combustion, simple chemical reactions*), and physical interactions of matter (*for example, velocity, force, work, power*), using word or symbolic equations; and
- describing and explaining physical interactions of matter using conceptual models (*for example, conservation laws of matter and energy, particle model for gaseous behavior*).

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For students continuing their science education beyond the standards, what they know and are able to do may include

- relating their prior knowledge and understanding of properties of matter to observable characteristics of materials and emerging technologies (*for example, semiconductors, superconductors, photovoltaics, ceramics*);
- modeling quantitative aspects of chemical and physical interactions (*for example, rates of reactions, stoichiometry, electromagnetic phenomena, statics and dynamics, electrochemistry*);
- applying knowledge and understanding of chemical and physical interactions to explore factors that influence or govern change (*for example, equilibrium constants, kinetics, thermodynamics*); and
- distinguishing among different types of constancy (*for example, static and dynamic equilibrium, symmetry, uniform/accelerated motion*) and different types of change (*for example, qualitative and quantitative trends, cyclic change, chaotic systems*).

STANDARD 3:

Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment. *(Focus: Biology--Anatomy, Physiology, Botany, Zoology, Ecology)*

3.1 Students know and understand the characteristics of living things, the diversity of life, and how living things interact with each other and with their environment.

RATIONALE

As a result of their study of a variety of organisms and where they live, students gain a better understanding of their world. Students have a natural curiosity about life and the great diversity of organisms. Their curiosity leads to the study of organisms and how the organisms interact with the world. Through the study of similarities and differences of organisms, students learn the importance of classification as a tool used by scientists. In their future as citizens, students will need to think about and make decisions about the diversity and extinction of organisms in their communities and the world.

GRADES K-4

In grades K-4, what students know and are able to do includes

- distinguishing living from nonliving things;
- classifying a variety of organisms according to selected characteristics *(for example, backbone vs. no backbone)*;
- describing the basic needs *(for example, food, water, air, shelter, space)* of an organism; and
- giving examples of how organisms interact with each other and with nonliving parts of their habitat.

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- constructing and using classification systems based on the structure of organisms;
- describing the importance of plant and animal adaptations, including local examples;

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- creating and interpreting food chains and food webs;
- explaining the interaction and interdependence of nonliving and living components within ecosystems; and
- describing how an environment's ability to provide food, water, space, and essential nutrients determines carrying capacity.

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- using and producing a variety of classification systems for organisms (*for example, the five-kingdom classification, classification based on behavior);*
- predicting and describing the interactions of populations and ecosystems;
- explaining how adaptations (*for example, structure, behavior)* of an organism determine its niche (role) in the environment;
- explaining how changes in an ecosystem can affect biodiversity and how biodiversity contributes to an ecosystem's stability; and
- analyzing the dynamic equilibrium of ecosystems, including interactions among living and nonliving components (*for example, tropical deforestation is linked to decreased global precipitation; Mount St. Helens' eruption had impact on the local ecosystem).*

Page S-20 contains suggestions for students who continue their science study beyond the scope of this standard.

3.2 Students know and understand interrelationships of matter and energy in living systems.

RATIONALE

From experience, students know that they must eat food to live. As a result of their study of energy movement (transfer) and change (transformation) in living organisms, students understand that the Sun is the primary and ultimate source of energy for living organisms. They learn why a constant input of matter and energy is critical for life. Photosynthetic organisms are critical to all organisms and need to be maintained. If one or more components are altered in an ecosystem, all other components are affected. Through studying the interrelationships of organisms, students learn that they can have a critical impact on other organisms.

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GRADES K-4

In grades K-4, what students know and are able to do includes

- recognizing that green plants need energy from sunlight and various raw materials to live, and animals consume plants and other organisms to live; and
- recognizing the interrelationships of organisms by tracing the flow of matter and energy in a food chain.

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- describing the basic processes of photosynthesis and respiration and their importance to life (*for example, set up a terrarium or aquarium and make changes such as blocking out light*);
- comparing and contrasting food webs within and between different ecosystems (*for example, grasslands, tundra, marine*) and predicting the consequences of disrupting one of the organisms in a food web;
- describing ways (*for example, digestion, transport of nutrients by circulatory system*) that multicellular organisms get food and other matter to their cells;
- explaining the recycling of materials by determining a pathway of a substance that is important for life (*for example, trace water through an ecosystem*); and
- describing the role of organisms in the decomposition and recycling of dead organisms (*for example, bacteria's role in the decomposition and recycling of matter from a dead animal*).

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- comparing and contrasting the processes of photosynthesis and respiration (*for example, in terms of energy and products*);
- explaining how simple molecules can be built into larger molecules within organisms (*for example, amino acids serve as building blocks of proteins; carbon dioxide and water are the basic materials for building sugars through photosynthesis*);
- explaining how large molecules (*for example, starch, protein*) are broken down into smaller molecules, serving as an energy source or as basic building blocks in organisms;
- explaining how energy is used in the maintenance, repair, growth, and development of tissues (*for example, in the production of new skin cells requires energy*); and
- describing the cycling of matter and the movement and change of energy through the ecosystem (*for example, some energy dissipates as heat as it is transferred through a food web*).

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Page S-16 contains suggestions for students who continue their science study beyond the scope of this standard.

3.3 Students know and understand how the human body functions, factors that influence its structures and functions, and how these structures and functions compare with those of other organisms.

RATIONALE

Students are interested in learning about their bodies and how they relate biologically to other forms of life. The study of structure and function, body organization, growth and development, and maintenance of other organisms enhances students' understanding of human development, health, and disease. Knowledge of these areas can assist students in making informed choices regarding nutrition, exercise, and other factors that influence how their body functions.

GRADES K-4

In grades K-4, what students know and are able to do includes

- describing human body systems (*for example, digestive, respiratory, circulatory, skeletal, muscular*);
- describing the basic food requirements for humans as summarized in the nutrition pyramid; and
- describing life cycles of selected organisms (*for example, frog, chicken, butterfly, radish, bean plant*).

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- describing the observable components and functions of a cell (*for example, cell membrane, nucleus, cytoplasm, chloroplasts; movement of molecules into and out of cells*);
- comparing and contrasting the basic structures and functions of different types of cells (*for example, single-celled organisms in pond water, Elodea, onion cell, human cheek cell*);
- describing the growth and development of several organisms (*for example, embryonic development of a vertebrate*);
- describing the structures and functions of human body systems; and
- describing and giving examples of noncommunicable diseases and communicable diseases (*for example, heart disease and chicken pox*).

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GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- describing cellular organelles and their function *(for example, the relationship of ribosomes to protein synthesis; the relationship of mitochondria to energy transformation);*
- differentiating among levels of organization *(cells, tissues, and organs)* and their roles within the whole organism;
- explaining human body functions in terms of interacting organ systems composed of specialized structures that maintain or restore health *(for example, mechanisms involved in homeostasis [balance], such as feedback in the endocrine system);*
- comparing and contrasting characteristics of and treatments for various types of medical problems *(for example, accidental, infectious, genetic);*
- using examples to explain the relationship of structure and function in organisms; and
- describing the pattern and process of reproduction and development in several organisms *(for example, earthworm, chick, human).*

Page S-20 contains suggestions for students who continue their science study beyond the scope of this standard.

3.4 Students know and understand how organisms change over time in terms of biological evolution and genetics.

RATIONALE

Students study the scientific concept of biological evolution--the changes in populations of organisms through time--in order to understand diversity and relatedness within the living world. Inquiries into evolution explain the ways in which natural processes produce life's diversity. These studies help students understand that evolution is the major unifying concept in the biological sciences and that it explains a wide variety of observations that can be made about the living world. In particular, students see that the study of evolution initiates questions about biodiversity, adaptation, genetics, mutations, the geological record, and the observed unity at molecular and whole-organism levels. This content standard does not define any student expectations related to the origin of life.

GRADES K-4

In grades K-4, what students know and are able to do includes

- identifying characteristics that are common to all individuals of a species *(for example, offspring resemble their parents);*
- recognizing that there are differences in appearance among individuals of the same population or group;

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- identifying characteristics of plants and animals that allow them to live in specific environments; and
- describing examples of extinct organisms based on fossil evidence *(for example, dinosaurs)*.

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- describing the purpose of body cell division and sex cell division;
- describing the role of chromosomes and genes in heredity *(for example, genes control traits, while chromosomes are made up of many genes)*; and
- describing evidence that reveals changes or constancy in groups of organisms over geologic time.

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- comparing and contrasting the purpose and process of cell division (mitosis) with the production of sex cells (meiosis);
- giving examples to show how some traits can be inherited while others are due to the interaction of genes and the environment *(for example, skin cancer triggered by over-exposure to sunlight or contact with chemical carcinogens)*;
- describing how DNA serves as the vehicle for genetic continuity and the source of genetic diversity upon which natural selection can act;
- describing how mutation, natural selection, and reproductive isolation can lead to new species and explain the planet's biodiversity;
- explaining why variation within a population improves the chances that the species will survive under new environmental conditions;
- describing the general structure and function of the gene (DNA) and its role in heredity and protein synthesis *(for example, replication of DNA and the role of RNA in protein synthesis)*; and
- calculating the probability that an individual will inherit a particular single gene trait *(for example, calculating the probability of offspring inheriting cystic fibrosis when both parents are carriers for the disease)*.

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For students continuing their science education beyond the standards, what they know and are able to do may include

- describing how, over long periods of time, ecosystems can remain stable and, if altered by factors such as climatic change, return to stability;
- explaining specializations that allow different types of cells to perform different functions;
- describing how balance (homeostasis) is maintained within an organism when its environment is altered (*for example, the relationship between blood glucose level and insulin production; carbon dioxide and oxygen balance in the body*);
- describing the role of gene mutations that result in uncontrolled cell division (*for example, cancer*);
- explaining the role of exposure to certain factors (*for example, chemical, biological, radiation*) that may increase the rate of mutation, and therefore the incidence of cancer and other diseases;
- determining the degree of kinship between organisms or species from estimations of the similarity of their nucleic acid sequences, which often closely match classifications based on anatomical similarities; and
- explaining how the rate of environmental change may exceed the capacity of organisms to respond to change, leading to the extinction of species.

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STANDARD 4:

Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space. *(Focus: Geology, Meteorology, Astronomy, Oceanography)*

4.1 Students know and understand the composition of Earth, its history, and the natural processes that shape it.

RATIONALE

By studying Earth, its composition, history, and the processes that shape it, students gain a better understanding of the planet on which they live. Landforms, resources, and natural events such as earthquakes, flooding, and volcanic eruptions affect the location of population centers. Life throughout geologic time has been, and continues to be, affected by changes that occur at a varying rate on Earth's surface. Knowledge of the structure and composition of the Earth provides a basis for making informed decisions. Understanding geologic events, such as earthquakes and volcanic eruptions, allows students to make responsible choices, evaluate the consequences, and predict the impact of future occurrences.

GRADES K-4

In grades K-4, what students know and are able to do includes

- describing different types and uses of Earth materials *(for example, rocks, soil, minerals);*
- recognizing that fossils are evidence of past life;
- identifying major features of Earth's surface *(for example, mountains, rivers, plains, hills, oceans, plateaus);*
- describing natural processes that change Earth's surface *(for example, weathering, erosion, mountain building, volcanic activity)*; and
- recognizing that humans are affected by natural events *(for example, earthquakes, volcanoes, floods).*

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GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- explaining how minerals, rocks, and soils form;
- explaining how fossils are formed and used as evidence to indicate that life has changed through time;
- modeling natural processes that shape Earth's surface (*for example, weathering, erosion, mountain building, volcanic activity*); and
- explaining the distribution and causes of natural events (*for example, earthquakes, volcanoes, landslides*).

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- describing the composition and structure of Earth's interior;
- using the theory of plate tectonics to explain relationships among earthquakes, volcanoes, mid-ocean ridges, and deep-sea trenches;
- using evidence (*for example, fossils, rock layers, ice cores, radiometric dating*) to investigate how Earth has changed or remained constant over short and long periods of time (*for example, Mount St. Helens' eruption*);
- evaluating the feasibility of predicting and controlling natural events (*for example, earthquakes, floods, landslides*); and
- analyzing the costs, benefits, and consequences of natural resource exploration, development, and consumption.

Page S-22 contains content suggestions for students who continue their science study beyond the scope of this standard.

4.2 Students know and understand the general characteristics of the atmosphere and fundamental processes of weather.

RATIONALE

Our Earth's atmosphere is vital to life. The Sun and atmosphere affect every aspect of our lives, including work productivity, food supply, energy use, transportation, recreation, environmental quality, and human health and safety. Weather-related choices we make range from selecting appropriate clothing to more complex situations, including preparing for and responding to hazardous weather. Preparedness and response to weather conditions require knowledge of how energy transfer influences atmospheric changes. The more we know about weather, the greater the chances that we will make informed decisions concerning its impact.

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GRADES K-4

In grades K-4, what students know and are able to do includes

- recognizing that the Sun is a principal source of Earth's heat and light;
- recognizing how our daily activities are affected by the weather (*for example, types of clothing, travel plans, recreational activity*); and
- describing existing weather conditions by collecting and recording weather data (*for example, temperature, precipitation, amount of cloud cover*).

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- describing the basic composition, properties, and structure of the atmosphere (*for example, the range and distribution of temperature and pressure in the troposphere and stratosphere*);
- observing, measuring, and recording changes in weather conditions (*for example, humidity, temperature, air pressure, cloud types, wind, precipitation*);
- explaining how atmospheric circulation is driven by solar heating (*for example, the transfer of energy by radiation, convection, conduction*); and
- describing large-scale and local weather systems (*for example, fronts, air masses, storms*).

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- analyzing the structure of, and changes in, the atmosphere, and its significance for life on Earth;
- explaining and analyzing general weather patterns by collecting, plotting, and interpreting data;
- describing how energy transfer within the atmosphere influences weather (*for example, the role of conduction, radiation, convection, and heat of condensation in clouds, precipitation, winds, storms*);
- investigating and explaining the occurrence and effects of storms on human populations and the environment; and
- describing and explaining factors that may influence weather and climate (*for example, proximity to oceans, prevailing winds, fossil fuel burning, volcanic eruptions*).

Page S-26 contains content suggestions for students who continue their science study beyond the scope of this standard.

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4.3 Students know major sources of water, its uses, importance, and cyclic patterns of movement through the environment.

RATIONALE

The world's water is vital to life. Both subtle and wholesale changes in Earth's water can have profound effects on human existence. In order to preserve both the quality and quantity of water for daily living, wise management of water resources is crucial. As the population and economies of the world grow, water becomes an even more important political and economic issue. Knowing the properties of water, its influences on weather, and its availability is necessary for understanding its importance to life. Knowledge of Earth's oceans is important for an understanding of how they affect weather, climate, and life. It is important to understand the circulation of water because the amount of water on Earth is finite.

GRADES K-4

In grades K-4, what students know and are able to do includes

- identifying major sources of water (*for example, oceans, glaciers, rivers, groundwater, atmosphere*);
- identifying and describing the states (*solid, liquid, gaseous*) in which water can be found on Earth; and
- recognizing the importance and uses of water (*for example, drinking, washing, irrigating*).

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- investigating and comparing the properties and behavior of water in its solid, liquid, and gaseous states;
- describing the distribution and circulation of the world's water through oceans, glaciers, rivers, groundwater, and atmosphere; and
- describing the composition and physical characteristics of oceans (*for example, currents, waves, features of the ocean floor, salinity*).

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- identifying and explaining factors that influence the quality of water needed to sustain life;
- identifying and analyzing the costs, benefits, and consequences of using water resources;
- explaining interactions between water and other Earth systems (*for example, the biosphere, lithosphere, and atmosphere*); and
- explaining interrelationships between the circulation of oceans and weather and climate.

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Page S-26 contains content suggestions for students who continue their science study beyond the scope of this standard.

4.4 Students know the structure of the solar system, composition and interactions of objects in the universe, and how space is explored.

RATIONALE

Observing the sky has always fascinated human cultures and civilizations. These observations resulted in the development of ways to measure time and predict natural phenomena. All bodies in space, including Earth, are influenced by forces acting throughout the solar system and the universe. Studying the universe enhances our understanding of Earth's origins, its place in the universe, and its future. Much of what we know about Earth's atmosphere and our solar system is due to space exploration. Modern society benefits from many of the technological advances developed for space exploration, including robotics, telecommunications, satellites, and miniaturized components used in computers and other electronic devices. Knowledge of the universe and past space exploration enables people to make informed decisions about the future of space exploration.

GRADES K-4

In grades K–4, what students know and are able to do includes

- describing what can be readily observed by the unaided eye in the daytime and nighttime sky (*for example, the Sun, Moon, planets, stars, constellations);*
- describing the motion of Earth in relation to the Sun, including the concepts of day, night, and year;
- recognizing the characteristics of seasons;
- identifying basic components of the solar system (*for example, Sun, planets, moons);* and
- describing a space exploration event such as a manned or unmanned space mission.

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GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- describing the basic components, composition, size, and theories of origin of the solar system;
- explaining the effects of relative motion and positions of the Sun, Earth, and Moon (*for example, seasons, eclipses, moon phases, tides);*
- comparing Earth to other planets (*for example, size, composition, relative distance from the Sun);* and
- identifying technology needed to explore space (*for example, telescopes, spectroscopes, spacecraft, life support systems).*

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- explaining the causes of and modeling the varied lengths of days, seasons, and phases of the Moon;
- describing the effect of gravitation on the motions observed in the solar system and beyond;
- describing electromagnetic radiation produced by the Sun and other stars (*for example, X-ray, ultraviolet, visible light, infrared, radio);*
- comparing the Sun with other stars (*for example, size, color, temperature);* and
- identifying and describing the everyday impact of recent space technology (*for example, more sophisticated computers, remote sensing, medical imaging).*

For students continuing their science education beyond the standards, what they know and are able to do may include

- explaining relationships and interactions between living things and Earth systems (*for example, the atmosphere, geosphere, and hydrosphere);*
- predicting possible climatic changes and their effects based on past and present climatic data;
- identifying and predicting natural hazards, using historical data;
- describing the life cycle of a star; and
- describing evidence that supports past and current scientific theories of the origin of the universe.

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STANDARD 5:

Students know and understand interrelationships among science, technology, and human activity and how they can affect the world.

RATIONALE

Our world is shaped in many ways by scientific advances, technology (involving applications of science), and human activity. Science and technology provide useful connections between the natural world and the designed world. Since the invention of stone tools, technological applications have provided, and will continue to provide, humans the ability to modify their environment. Because scientific advances and technology affect all of Earth's living and non-living systems, it is vital that students understand the interrelationships of science, technology, and human activity.

GRADES K-4

In grades K-4, what students know and are able to do includes

- recognizing the diversity of resources provided by the Earth and Sun (*for example, soil, fuels, minerals, medicines, food*);
- inventing a device that addresses an everyday problem (or task), and communicating the problem (or task), design, and solution;
- describing resource-related activities in which they could participate that can benefit their communities (*for example, recycling, water conservation*); and
- identifying careers that use science and technology.

GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- investigating and describing the extent of human uses of renewable and non-renewable resources (*for example, forests, fossil fuels*);
- describing advantages and disadvantages that might accompany the introduction of a new technology (*for example, mountain bikes, cellular telephones, pagers*);
- describing how the use of technology can help solve an individual or community problem (*for example, using catalytic converters on automobiles to help reduce air pollution*); and
- describing how people use science and technology in their professions.

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- analyzing benefits, limitations, costs, and consequences involved in using technology or resources *(for example, X-rays, agricultural chemicals, natural gas reserves)*;
- analyzing how the introduction of a new technology has affected or could affect human activity *(for example, invention of the telescope, applications of modern telecommunications)*;
- demonstrating the interrelationships between science and technology *(for example, building a bridge, designing a better running shoe)*; and
- explaining the use of technology in an occupation.

For students continuing their science education beyond the standards, what they know and are able to do **may** include

- applying their knowledge and understanding of chemical and physical interactions to explain present and anticipated technologies *(for example, lasers, ultrasound, superconducting materials, photocopy machines)*; and
- exploring the scientific and technological aspects of contemporary problems *(for example, issues related to nutrition, air quality, natural resources)*.

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STANDARD 6:

Students understand that science involves a particular way of knowing and understand common connections among scientific disciplines.

RATIONALE

Human societies have long asked questions about, observed and collected data on, and offered explanations for natural phenomena. Scientific evidence and knowledge are distinguished from other ways of knowing and other bodies of knowledge in terms of the criteria that must be met. These criteria include the use of empirical standards and rules of evidence, a logical structure, rational thought, questioning, and openness to criticism. Scientific disciplines differ from one another in what is studied, techniques used, and outcomes sought. They share a common purpose—to explain and predict events and phenomena—and offer strategies to solve defined problems. Scientific knowledge is dynamic. Although some scientific theories have withstood the test of time and are still used, other knowledge claims have been altered by new scientific evidence. Change, continuity, and stability are characteristic features of science.

Although acquiring scientific knowledge of laws, concepts, and theories is central to learning science, it does not necessarily lead to an understanding of how science itself works. Students need to understand that science works by weaving different aspects of science together so that they reinforce one another. To bring coherence to seemingly diverse sets of ideas or facts involving natural phenomena, scientific themes such as change, systems, models, and organization are highly useful. Themes can encompass and connect large quantities of basic data and evidence in science and can be used to integrate science with other disciplines.

GRADES K-4

In grades K-4, what students know and are able to do includes

- recognizing that when a science experiment is repeated with the same conditions, the experiment generally works the same way;
- comparing knowledge gained from direct experience to knowledge gained indirectly (*for example, collecting data about student heights in their class and comparing the results to similar data collected in another class or school*);
- identifying observable patterns and changes in their lives and predicting future events based on those patterns (*for example, seasonal weather patterns*);
- describing and comparing the components and interrelationships of a simple system (*for example, tracing the continuous flow of water through an aquarium, filter, and pump*); and
- comparing a model with what it represents (*for example, comparing a map of the school to the actual school; a model of the Earth to the Earth itself*).

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GRADES 5-8

As students in grades 5-8 extend their knowledge, what they know and are able to do includes

- explaining why a controlled experiment must have comparable results when repeated;
- giving examples of how scientific knowledge changes as new knowledge is acquired and previous ideas are modified (*for example, through space exploration);*
- describing contributions to the advancement of science made by people in different cultures and at different times in history;
- identifying, comparing, and predicting variables and conditions related to change (*for example, climate, population, motion);*
- identifying and illustrating natural cycles within systems (*for example, water, planetary motion, geological changes, climate)*; and
- using a model to predict change (*for example, computer simulation, video sequence, stream table).*

GRADES 9-12

As students in grades 9-12 extend their knowledge, what they know and are able to do includes

- evaluating print and visual media for scientific evidence, bias, or opinion;
- explaining that the scientific way of knowing uses a critique and consensus process (*for example, peer review, openness to criticism, logical arguments, skepticism);*
- using graphs, equations, or other models to analyze systems involving change and constancy (*for example, comparing the geologic time scale to shorter time frames);*
- analyzing and comparing models of cyclic change as used within and among scientific disciplines (*for example, water cycle, circular motion, sound waves, weather cycles);*
- identifying and predicting cause-effect relationships within a system (*for example, the effect of temperature on gas volume, effect of carbon dioxide level on the greenhouse effect, effects of changing nutrients at the base of a food pyramid);*
- identifying and describing the dynamics of natural systems (*for example, weather systems, ecological systems, body systems, systems at dynamic equilibrium);*
- identifying and testing a model to analyze systems involving change and constancy (*for example, a mathematical expression for gas behavior; constructing a closed ecosystem such as an aquarium);*
- explaining an exponential model (*for example, pH scale, population growth, Richter scale);* and
- refining a hypothesis based on an accumulation of data over time (*for example, Alvarez's theory on dinosaur extinction.*).

For students continuing their science education beyond the standards, what they know and are able to do **may** include

- relating small-scale phenomena to large-scale properties (*for example, intermolecular forces related to physical properties*); and
- tracing the development of an invention, theory, or discovery to demonstrate the dynamic nature of science.

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